National Aeronautics and Space Administration

# goddard tech trends

## High-Tech Spelunking

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# High-Tech Spelunking

## *Goddard Engineers Build the CAVE, a 3D Immersive Environment*


*John Van Eepoel (seated) and Steve Queen use a special workstation to operate the Goddard CAVE, which is located in Building 28. The new, fully immersive environment was developed in part with R&D funds.*

No one has bent a scrap of metal, but at least one of the four spacecraft to be built as part of NASA's Magnetospheric Multiscale (MMS) mission exists — and not just on paper or on a computer screen, either. It exists in its 3D holographic glory, suspended in a pitch-black, room-sized cube, surrounded by a gazillion stars.

Welcome to the CAVE — Goddard's newest visualization tool.

Now open for business, the facility is available to any engineer or scientist who needs to "see" and interact with complex systems before he or she actually commits to their designs.

"In essence, what we do is use our high-fidelity simulation capabilities to visualize 3D models developed in CAD (computer-aided design) packages as they would move under the laws of physics," said Dave Folta, an aerospace engineer who, along with his colleague, Steve Queen, created the facility for Goddard's Mission Design and Navigation Branch (MDNB). "Our facility is stereoscopic and fully immersive," Queen added. "You can actually walk around the object you've created."

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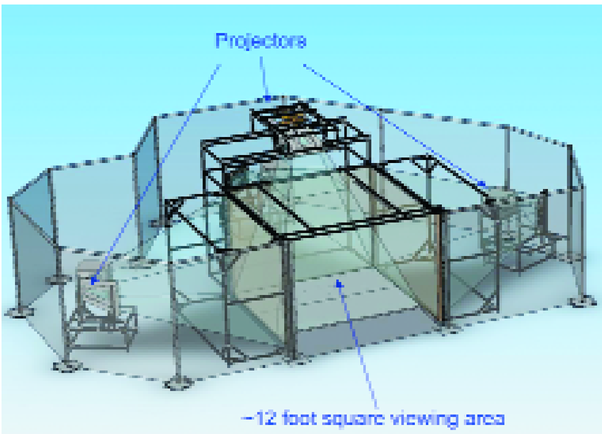
## About The Cover:

*Aerospace engineer Dave Folta goes spelunking in the Goddard CAVE, a fully immersive visualization facility that simulates an orbital environment to an unprecedented level of realism. Folta and his colleague, Steve Queen, began developing the CAVE about three years ago. Their goal was to create a tool that would allow engineers to "see" complex space systems before committing to an actual design. The Goddard CAVE is now open for business.*

Photo Credit: Chris Gunn

## Spelunking... *Continued from page 2*

Manufactured by Christie Digital Systems and SGI, the CAVE is appropriately named: it is a dark, relatively small space measuring only 12 feet x 12 feet x12 feet. To experience the CAVE, users wear special 3D eyewear and carry a wand to command and control the visualizations. The facility's Linux-based visualization system projects images onto three walls and the floor to create the fully immersive environment.




### Simulated Orbital Environment

Efforts to develop such a capability began more than three years ago when Folta visited an immersive environment at Purdue University, which at the time was co-researching dynamical systems and libration-orbit trajectories under a grant with Goddard. "I thought to myself, 'we've got to get one of these,'" he recalled. At about the same time, Queen started working on algorithms and other technology to develop a workstation simulator to help plan the Hubble Space Telescope Robotic Servicing and De-orbit mission. When NASA canceled that mission, Queen continued his work using Internal Research and Development (IRAD) program funding.

Queen and Folta ultimately joined forces, working part-time to raise funds to buy the equipment and renovate the Building 28 office space that would house the facility.

Although visualization environments aren't new, and today are used by a myriad of industries and universities, no one has created a simulated orbital environment that offers the same level of realism. "We've done the legwork of creating the surroundings; all our people need to do is fill in the space," Queen added.

Various projects have begun to do just that. The MMS project used the CAVE to better understand the dynamics of the spacecraft's body and Folta has begun to use the technology to visualize complex trajectories. Bo Naasz, an IRAD principal investigator, is developing navigation algorithms and a high-fidelity simulation of a landing on a small celestial body. His CAVE demonstration is planned for late this year. The MDNB plans to use the CAVE for the Lunar Reconnaissance Orbiter and Mars Atmosphere and Volatile Evolution missions.

Folta says the CAVE also is ideal for visualizing complex attitude-control technologies, astrophysics- and Earth-related science missions, or the hazards a rover might encounter on the Moon or Mars.

"This isn't a one-way street," Folta said. "It's not just for visualizing output from a CAD." He envisions users designing systems in the CAVE so that they see and experience those designs in real time. "We're just in our infancy as to what we can do with this facility." ◆

**Contact:**

David.C.Folta@nasa.gov or 301.286.6082
Steven.Z.Queen@nasa.gov or 301.286.0988

## The DREAM Team

### *Team Studies Sun-Moon System*

Thanks to R&D funding, Goddard's very own "DREAM Team" has won $5 million to develop advanced computer models that explore the interactions of solar radiation and solar wind on the Moon.

The four-year research effort, funded by NASA's Lunar Science Institute, kicks off in April and is aimed at investigating interactions most likely to affect human explorers — solar storms, the electric charging of lunar dust, and the erosion of potential water resources at the poles, said Bill Farrell, principal investigator of the Dynamic Response of the Environment at the Moon (DREAM) proposal effort.

"Many people think of the Moon as dead, but if you look with a different pair of glasses — at the atomic level — it's very active," Farrell added. "The Sun is constantly throwing energy and matter into space, including radiation and a million-mile-per-hour stream of charged particles called the solar wind. When you put something in front of this, like the Moon, that object gets hit and reacts. That's the point of this research — to investigate those interactions."

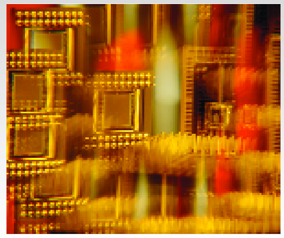
Getting to the bottom of those questions will require the DREAM team to develop sophisticated and highly advanced computer simulations — a capability Farrell initially developed through Internal Research and Development program funding. "One of our roles will be to provide modeling support to scientists examining data from NASA's lunar science missions, such as Goddard's Lunar Reconnaissance Orbiter. Scientists always are surprised by what they discover in science and our computer models can help them understand their results," Farrell said. ◆

**Contact:**

William.M.Farrell@nasa.gov or 301.286.4446

**SPECIAL REPORT: Early-Stage Innovations: A Glimpse at the Future?**

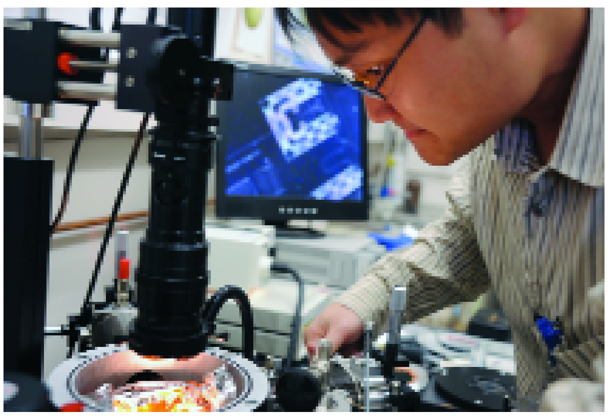
*What's the next best technology, the innovative new approach that will enable never-before-imagined science or significant leaps in capability? In this issue of Goddard Tech Trends, we provide snapshots of a few of the Center's "early-stage innovations." The technologists who are pursuing these longer-range technologies could*



*provide the revolutionary new capability needed to enable next-generation astrophysics, Earth science, or heliophysics missions. These technologies, which could take years to mature, would secure Goddard's expertise in areas that the Center has deemed important to its future. (Photo Credits: Debora McCallum)*

## Scaling Up Detector Arrays

Obtaining high-resolution data of faint or very distant objects will require technologists to build instruments equipped with large detector arrays containing literally thousands of tiny pixels. Getting to that next level of sophistication, however, is easier said than done. Technologists not only have to develop ways to more easily assemble these detector arrays, they also have to come up with better ways to "wire" them so that the data they collect are efficiently transmitted to read-out systems.



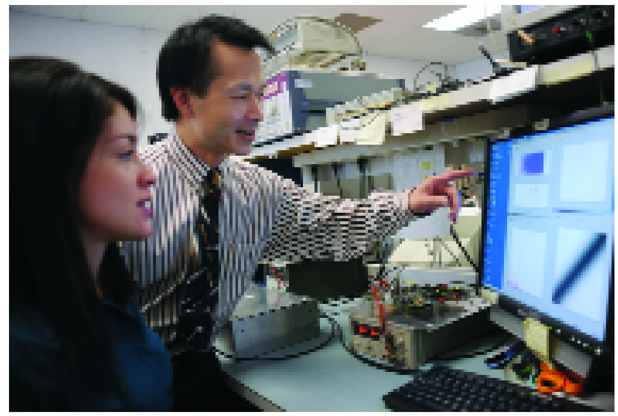
"If you have 10,000 detectors, you'll have at least 10,000 terminals to be wired," says Goddard technologist Kongpop U-Yen. "We're trying to minimize the number of output wires." Under his R&D funding, U-Yen's team is developing a technique where the pixels would share the same transmission line, freeing up space, and ultimately improving technologists' ability to scale up the pixel density needed for next-generation missions like the Beyond Einstein Inflation Probe and the International X-ray Observatory (formerly called Constellation-X), to name a few. ◆

Contact:Kongpop.U-yen-1@nasa.gov or 301.286.6233

## Compressing Radar Data

Remote-sensing instruments generate copious amounts of information, which must be compressed and stored until the user retrieves the data. Not only are data-processing systems complex — requiring, for one, a complicated data-sampling step — errors can propagate when the user decompresses the information.

Goddard technologist Wai Fong thinks there is a better way. He and his team are trying to develop new ways to

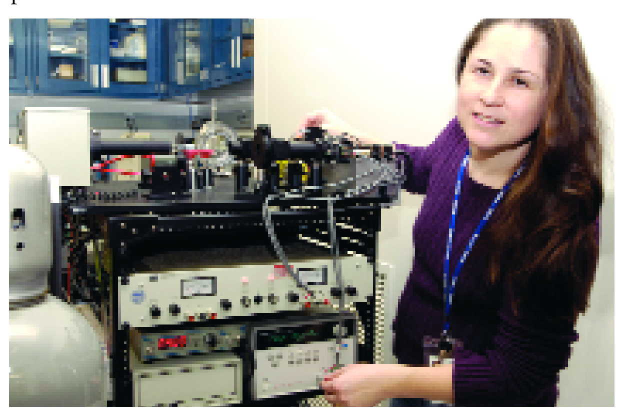


record the data so that they are sampled and compressed in one simple process on the instrument itself. This would eliminate the need for complex onboard data-processing equipment, which would reduce spacecraft weight — always an important concern for mission planners, he says. Although he is focused now on radar applications, it is conceivable that the technology ultimately could be applied to other types of measurements. ◆

Contact: Wai.H.Fong@nasa.gov or 301.286.8165

## Measuring Martian Methane

In January, Goddard scientist Mike Mumma announced he had used ground-based telescope data to definitively detect methane plumes in the northern hemisphere of Mars. Its detection made headlines because it showed that Mars still could be alive — either biologically or geologically. Not surprisingly, discovering the source of these gases is a science priority and will require additional missions to the planet itself.



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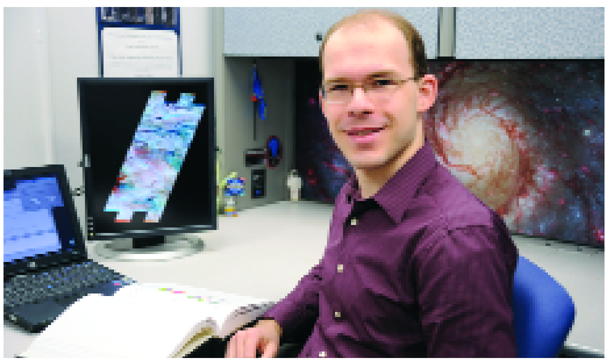
Goddard scientist Emily Wilson believes a smaller gas correlation radiometer, particularly one that implements a hollow-optical fiber to reduce the size of the instrument, offers an ideal solution for globally pinpointing the source of methane on Mars. R&D funding is allowing her to develop this reduced-size instrument and make it viable for a Mars orbiter or lander mission. "We're getting close," she says. ◆ Contact:Emily.L.Wilson@nasa.gov or 301.614.6155

## Tailoring Hyperspectral Datasets

Earth scientists can learn much from hyperspectral data — everything from identifying mineral deposits and land-use changes to detecting and mapping fires, chemical spills, and even floods. However, only a small portion of a hyperspectral image is useful for identifying any given material, says scientist Kevin Fisher. Furthermore, material-classification programs that analyze images run slowly because these images contain so much data.



Under a new R&D effort, Fisher is developing a system that creates reduced datasets tailored to each potential application, whether it's looking for a specific mineral or mapping wildfires in California. In particular, Fisher is developing an algorithm to quickly analyze hyperspectral images and select the most useful spectral bands for a given science application.

The ultimate goal, he says, is to perform image analysis on the spacecraft itself. That way, "the spacecraft can make more intelligent decisions about what to observe," Fisher says. "It would be like an onboard scientist analyzing the images." ◆ Contact: Kevin.Fisher@nasa.gov or 301.286.9605

## Advancing a New Type of Refrigerator

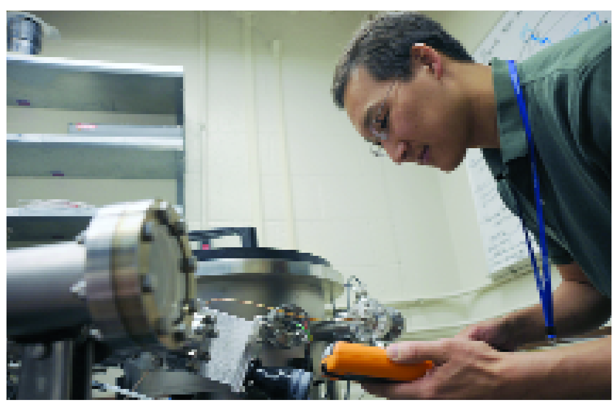
Goddard is the world-renowned expert in building cooling technologies for astronomical instruments. Goddard technologist Franklin Miller would like to continue that legacy.

With R&D funding, Miller is developing technologies needed for the next-generation Sub-Kelvin Active Magnetic Regenerative Refrigerator, a new type of technology that would cool infrared bolometers and X-ray microcalorimeters needed for the International X-ray Observatory and other missions.

In particular, Miller developed an efficient thermodynamically reversible pump, which has no moving parts, to force a mixture of helium 3 and helium 4 in a temperature range below 1.7 Kelvin. Now, he's advancing the capabilities of other components. The technology "allows greater flexibility and lowers mass," Miller said. "This is another step beyond." ◆ Contact:Franklin.K.Miller@nasa.gov or 301.286.6543

## Building a Miniaturized Mass Spectrometer

Discovering the origin and history of Mars, Venus, the Moon, comets, and geologically active moons orbiting Saturn will require that scientists measure volatiles using a mass spectrometer, similar to the one that Goddard is building for the Mars Science Laboratory. But the next-generation mass spectrometer will have to be smaller and even more capable to obtain the type of measurements that would determine the potential for past or present life on these worlds.

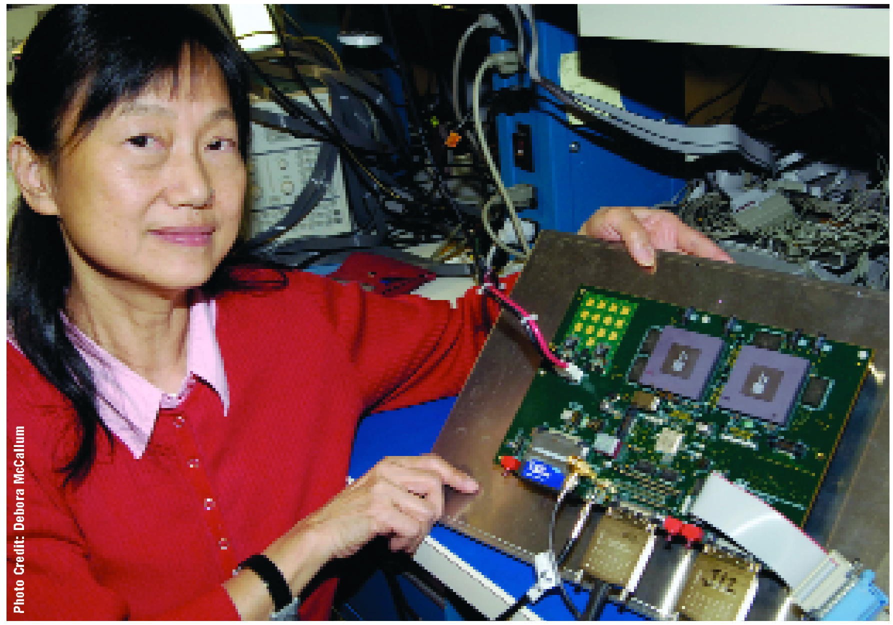


Principal Investigator Todd King is on the case. Using R&D funding, he and his team have demonstrated the theoretical basis for a small, low-weight, high-resolution time-of-flight mass spectrometer. The team is employing micro- and nano-fabrication methods to build components that will result in a miniaturized, more capable instrument, King says. "The work we're doing is a significant step toward a substantially more resource-efficient, high-performance mass spectrometer for space use." ◆ Contact: Todd.T.King@nasa.gov or 301.286.4197

# A Fortuitous Meeting

## *Goddard Team Develops Flexible Data-Compression Technology*

The instrument that Goddard scientist Tom Moore currently is developing for the Magnetospheric Multiscale (MMS) mission is expected to generate two megabytes of data per second — a rate of data that is analogous to streaming video over a computer. While it's easy on Earth with high-speed Internet, it's difficult in space where the data rate would quickly overwhelm the mission's bandwidth allocation for downlinking data.




*Pen-Shu Yeh's data-compression chips will fly on the Fast Plasma Investigation, an instrument on the Magnetospheric Multiscale mission.*

But that's never been a concern for Moore.

Moore and his team were aware of and actively developing new methods to compress data when he had the good fortune of meeting Goddard technologist Pen-Shu Yeh about six years ago. Knowing that his Fast Plasma Investigation (FPI) would generate a data flow typical of video transmissions and many times greater than those of previous space-plasma instruments, she offered the perfect solution to his data conundrum. She had developed a highly sophisticated data-compression algorithm that promised to be more flexible in decreasing the volume of data sent back to Earth than its predecessor.

That promise is now a reality.

### Two Chips Manufactured, Tested

Last summer, the University of Idaho's Center for Advanced Microelectronics and Biomolecular Research, Yeh's partner in the effort, successfully fabricated two high-end radiation-hardened processors — the Discrete Wavelet Transformer and a Bit Plane Encoder. The chips recently underwent testing, proving that they could compress 40 megabytes of data per second and could function well in a radiation environment. That data rate far surpasses the stringent data-compression needs of Moore's instrument.

"Because these two chips implement a data-compression algorithm for space standards issued by the Consultative Committee for Space Data Systems, we expect direct applications to many future missions." Yeh said.

### Data Return Critical

The need for such a capability can't be understated — particularly for MMS. MMS will employ four identically instrumented spacecraft to make coordinated high-resolution observations of plasma in Earth's magnetosphere, the highly magnetized region that surrounds the planet.

As part of this mission, the FPI specifically will take rapid measurements — as often as 30 times per second — the pressure, temperature, and heat flow of plasma, which is created when heat or energy interacts with gas and causes a significant number of atoms to release some or all of their electrons. The remaining parts of those atoms are left with a positive charge and the detached negative electrons are free to move about. As a result of this process, plasma is electrically conductive and easily manipulated by magnetic fields. Scientists need the FPI measurements to understand the operation of a process called magnetic reconnection, which causes flares and coronal mass ejections in the Sun and magnetic storms in Earth's atmosphere, Moore said.

From a macro view, these measurements and others also will help scientists better understand the Sun and its effects on Earth, the solar system, and the environment where human explorers will work. And because plasma is the most abundant form of matter in the universe, the mission will provide invaluable insights into other astrophysical phenomena.

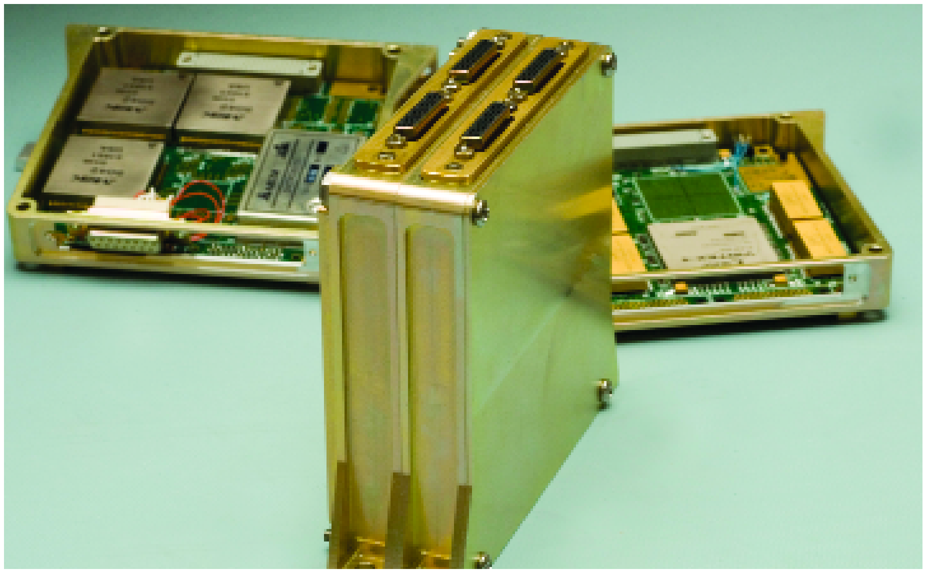
### 'They're Pioneers'

For Yeh, who used a small amount of Internal Research and Development funding to help demonstrate the technology, the effort has been a rewarding one. "We worked closely with [Moore's team]. They had confidence in us and were willing to be the first mission to use the technology. I would say they're pioneers," she said. ◆

**Contact:**

Pen-shu.Yeh-1@nasa.gov or 301.286.4477

# What Would You Rather Have: More Data or Perfect Data?



*SpaceCube is a small hybrid computer that provides up to 25 times the processing power of a typical flight processor. Technologists are now developing a next-generation version that offers100 times more data.*

Given a choice, what would most mission scientists prefer: a traditional radiation-hardened computer processor that generates perfect data all the time or a new technology that offers advanced capabilities and collects and processes 100 times more data — with maybe an occasional bad pixel or two?

Goddard technologist Tom Flatley bets that many scientists would choose the latter.

NASA's Advanced Information Systems Technology (AIST) program thinks so, too, and awarded Flatley a $1.1 million, three-year task to build such a data-processing capability. The next-generation system will be based on SpaceCube, an experimental computer system that Goddard engineers designed a few years ago. It will be demonstrated for the first time in May during the Hubble Space Telescope Servicing Mission (see *Tech Trends*, Summer 2008, page 3).

"SpaceCube is an excellent stepping stone toward true next-generation onboard processing capabilities," said Flatley, who has used Internal Research and Development funds to develop other science applications for the technology.

## Order-of-Magnitude Increase in Computing Power

For one, it offers several advantages over traditional radiation-hardened flight processors. Mission planners can reconfigure SpaceCube "on the fly," which means they can implement algorithms that allow the spacecraft to detect and react to events or to produce data products onboard, thereby reducing onboard data-storage requirements. Just as important, SpaceCube provides 10 to 25 times the processing power of a typical Rad750 flight processor.

But the original SpaceCube has its problems, too. The technology uses commercial-grade fault-tolerant components, which are considerably less expensive than radiation-hardened components. But because they aren't fully hardened against the ill effects of radiation, SpaceCube is prone to radiation upsets. To overcome these problems, Flatley has developed algorithms that computationally correct these errors on orbit.

Flatley concedes, however, that even with these mitigation techniques, the original SpaceCube will not be totally immune from critical upsets. "Because of these issues, the current experimental SpaceCube can't meet 'operational' mission requirements," Flatley said.

## Big Plans Ahead

Enter SpaceCube 2.0.

With his $1.1 million in AIST funding, Flatley is developing the breadboard and flight prototype of the next-generation SpaceCube computer. He will leverage both his "radiation-hardened-by-software" techniques and a new radiation-hardened field programmable gate array (FPGA) that the San Jose-based company, Xilinx, developed with Air Force funding. (FPGAs are semiconductors that users can reprogram after they're manufactured. In other words, users can program them to carry out any logical function that an application-specific integrated circuit would perform.)

By combining the new FPGA with the software-mitigation techniques, Flatley said the next-generation SpaceCube will be more immune to so-called "single-event upsets," which occur when a radiation particle hits some part of the logic and changes a "one" to a "zero," or visa versa.

Flatley plans to test an intermediate version — SpaceCube 1.5 — on a sounding rocket flight this fall. "Our ultimate goal, though, is to provide the science community with the choice between perfect data using a traditional radiation-hardened processor or 100 times more data, plus next-generation capabilities, with maybe an occasional bad pixel using SpaceCube 2.0," Flatley said. ◆

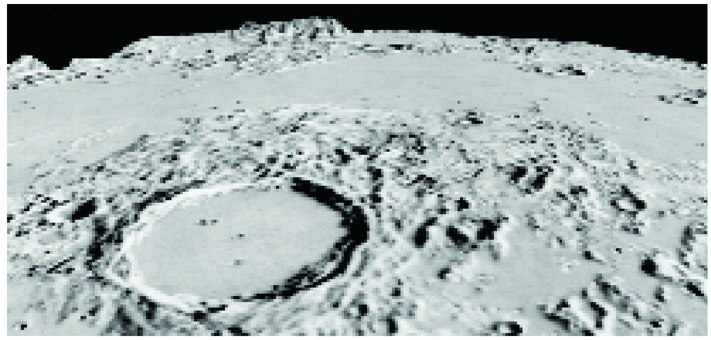
**Contact:**

Thomas.P.Flatley@nasa.gov or 301.286.7029

# On the Side of Winners

## *Goddard-Developed Geospatial Information System Attracts Exploration Interest*

In the R&D world, you win some and you lose some. These days, Principal Investigator Steve Talabac definitely is in the company of winners.



*This image, taken by Clementine of the lunar terrain, is a sample of the data that would be available on ILIADS, a Goddard-developed geospatial information system.*

After two years of developing a software application that provides easy access to geographic and environmental lunar data (see *Tech Trends*, Spring 2007, page 4), NASA's Exploration Systems Mission Directorate (ESMD) is taking notice. In recent months, various EMSD organizations have tapped Talabac's team to help develop lunar-mission planning tools that would require the capabilities offered by ILIADS, the geospatial information system technology he began developing under the Internal Research and Development program.

### Applications for ILIADS

NASA's Lunar Mapping and Modeling Project (LMMP) is one.

LMMP is an information system now being developed by Goddard, the Jet Propulsion Laboratory (JPL), the Ames Research Center, the U.S. Geological Survey, and the U.S. Army Corps of Engineers. Mission planners will use LMMP to locate mapped lunar data, such as digital elevation models and illumination, temperature, and resource maps. Goddard is contributing an enhanced version of its ILIADS software to interface with a JPL-developed Web portal and lunar-data product server. Talabac said the team plans to release a prototype system in November. The team will demonstrate the prototype to the Constellation Program user community.

Another project that sought the services of the ILIADS team is the Lunar Surface Operations Simulator (LSOS), which JPL is developing to model and simulate the performance of lunar rovers.

Talabac's team is enhancing the ILIADS software to include a tool suite that helps define waypoints or geographical reference points that an astronaut might follow to reach a particular destination. The JPL-developed LSOS would then use the reference points to simulate a rover traveling along the defined path. In particular, the planners would want to make sure the rover could safely traverse the plotted course and that it had sufficient sunlight to power its subsystems throughout the journey. "LSOS results would be fed back to ILIADS so that the mission planner could modify the path if the simulation indicated a potential problem," Talabac said.

And last, Talabac's group is working with Richard Lynch, an IRAD-funded principal investigator, who is developing a concept for another navigational capability, called the Lunar Navigation Determination System. This proposed technology would provide location and navigational information to astronauts roving on the Moon. "This would be akin to a GPS system in your car," Talabac said, adding that ILIADS would provide the user interface because of its ability to access and display 3D topographical and thematic maps and superpose them with the rover's location.

"The return on investment in ILIADS has clearly paid off, and we hope to add additional analytical and visualization capabilities to ILIADS to benefit the Constellation Program," Talabac said. ◆

**Contact:**

Stephen.J.Talabac@nasa.gov or 301.286.1452

## Goddard Tech Trends

*Goddard Tech Trends* is published quarterly by the Office of the Chief Technologist at the Goddard Space Flight Center in Greenbelt, Maryland. The newsletter describes technology developments at Goddard and explains how they are helping NASA to achieve its missions. If you want more information about Goddard technology, contact the Chief Technologist. If you wish to be placed on the newsletter distribution list, contact the editor. **NP-2007-10-853-GSFC (revised 4/09)**

Peter M. Hughes
Chief Technologist
301.286.2342
Peter.M.Hughes@nasa.gov

Lori J. Keesey
Editor
301.258.0192
ljkeesey@comcast.net